Using GV Field Campaign Data to Improve GPM Algorithm Assumptions

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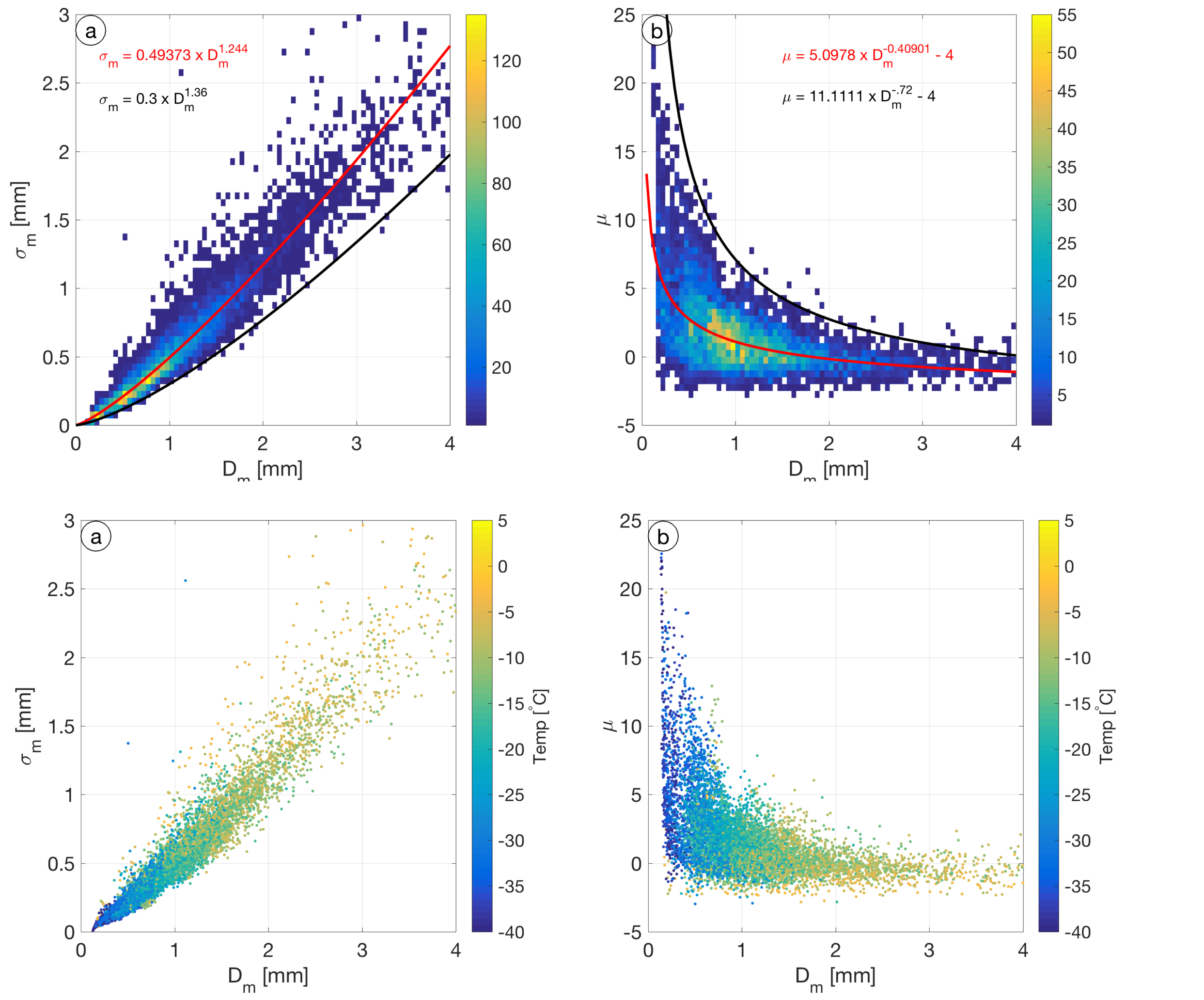
Here, we address two key assumptions of GPM retrieval algorithms in ice-phase precipitation using GCPEx, MC3E, and OLYMPEX UND Citation and radar observations:

1) Parameterization of ice cloud particle size distributions (PSDs): *Use the Williams et al. (2014) $\sigma_m - D_m$ framework to retrieve μ using statistically uncorrelated estimates* (Borque et al., in prep)

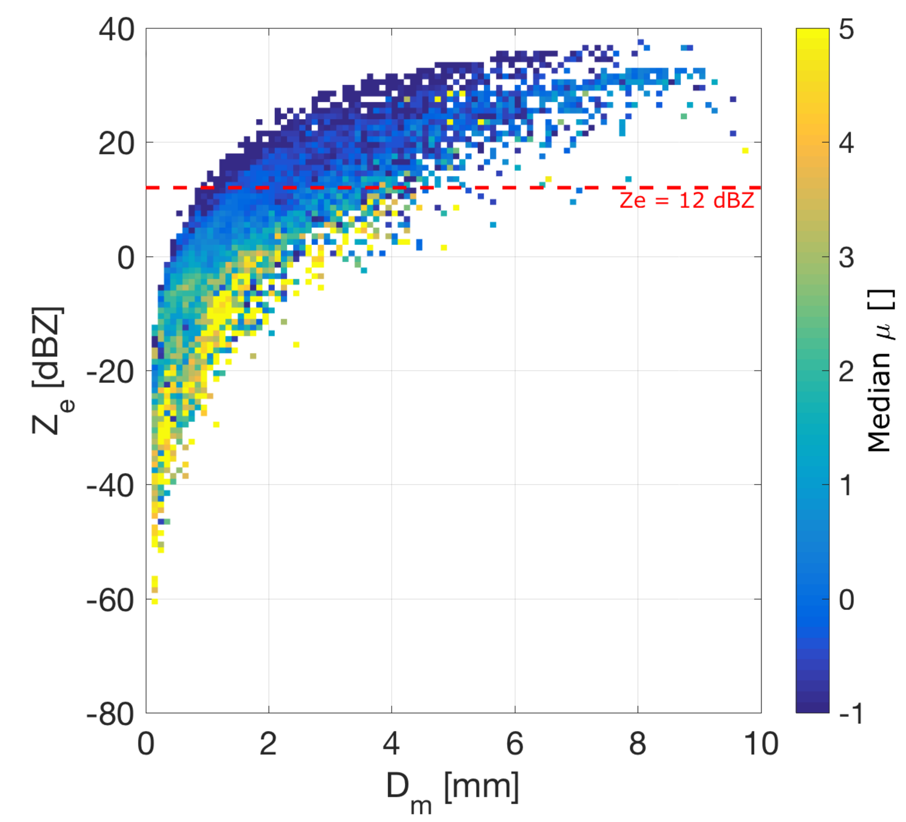
$\sigma_m - D_m$ in GCPEx ice only clouds



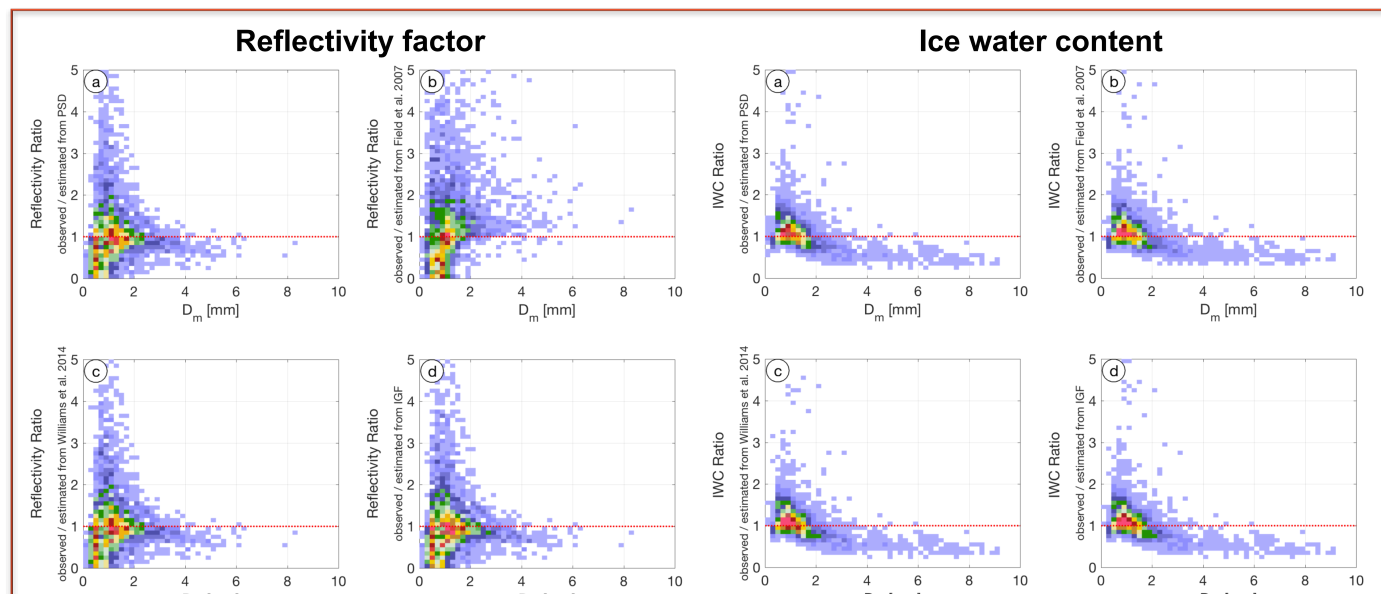
Uncorrelated mass parameters (top), and PSD variability with temperature (bottom, shaded in °C)
Red (this study using Heymsfield et al. 2010 a and b mass parameters)
Black (Williams et al. 2014 relationships in rain)
PSDs from NCAR

$Z_e - D_m$ in GCPEx ice only clouds

Radar reflectivity factor (Z_e, simulated using PSDs, $0.6{*}D_{max}$, prolate particles at C-Band using Self-Similar Rayleigh Gans - SSRG; Hogan and Westbrook 2014) shows that GPM-detectable D_m is the minority of points observed by the Citation in ice-only conditions, D_m > 1-2 mm. **Large μ found at small D_m not relevant for GPM retrievals.**



Comparison of estimated and observed Z_e and ice water content (IWC)

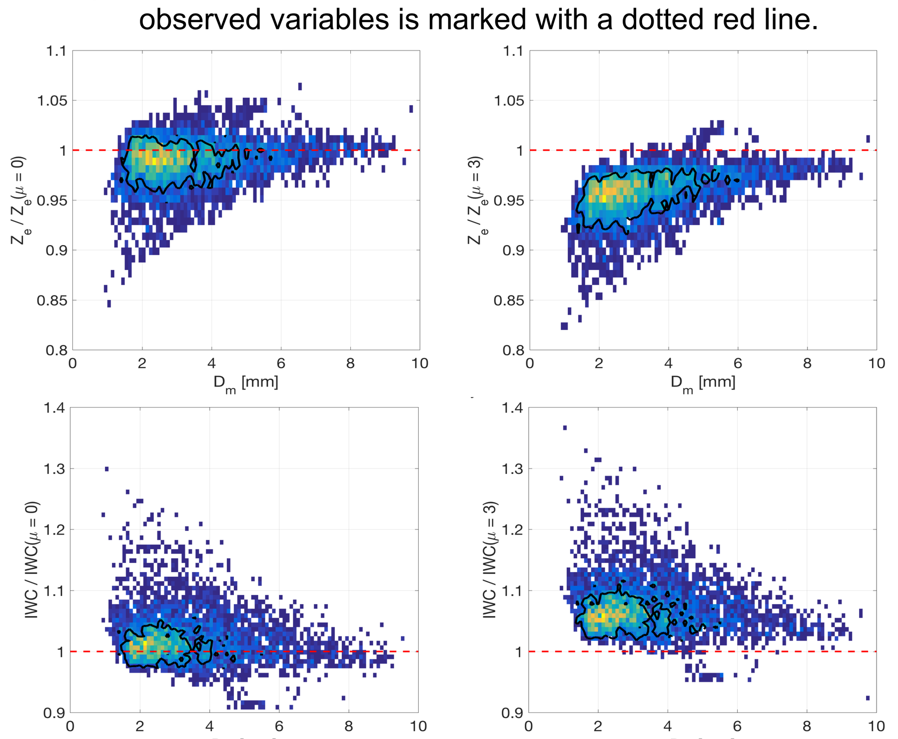


Radar reflectivity factor observed by the Environment Canada King City C-Band radar is compared with C-Band SSRG (expressed as a ratio – left panels), and IWC observed by the Nevzorov probe is compared with the PSD IWC (expressed as a ratio – right panels) as a function of D_m for 4 PSDs:(a) observed PSDs, (b) Field et al. (2007) parameterization (used in CloudSat snowfall retrievals), (c) moment-based parameterization developed in this study, and (d) incomplete Gamma fit (McFarquhar et al. 2015).

Observed, moment-based, and IGF perform nearly identically. Field et al. (2007) has more scatter and is biased high in Z_e at D_m > 2 mm. All parameterizations are low in IWC relative to Nevzorov measurements at D_m > 2 mm.

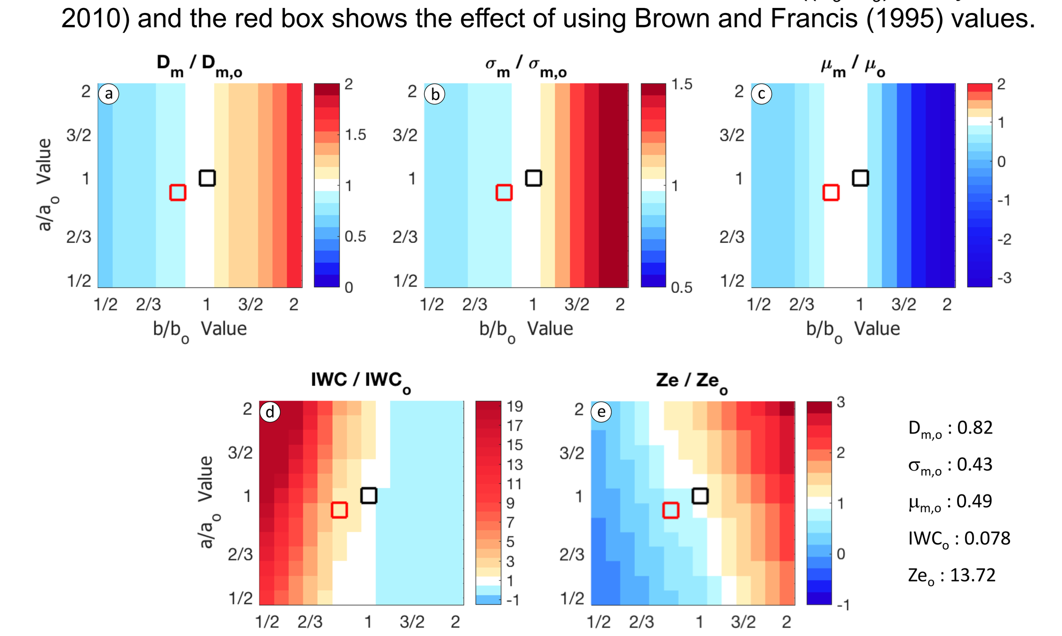
Impact of μ on forward-modeled Z_e and IWC

Normalized joint frequency of occurrence of Z_e with varying μ divided by Z_e estimated with μ equal to (a) zero and (b) three versus D_m. Frequencies larger than 0.25 are enclosed by the solid black line and a zero difference between the estimated and observed variables is marked with a dotted red line.



Uncertainty due to *a* and *b* assumptions

Influence of different a and b parameters, via the mass-diameter relation, in (a) D_m, (b) σ_m, (c) μ, (d) IWC, and (e) Z_e. This effect is quantified by estimating the mass for different *a* and *b* values (ranging from half to double the values used in this work – (a_o, b_o)) and calculating the associated moments and variables normalized by the ones using (a_o, b_o). Therefore, a value of 2 (0.5) indicates that, for the corresponding (*a*, *b*) value, there is a 100% positive (50% negative) bias in the estimated variable. The black box shows the values used in this work ((a_o, b_o) – Heymsfield et al., 2010) and the red box shows the effect of using Brown and Francis (1995) values.



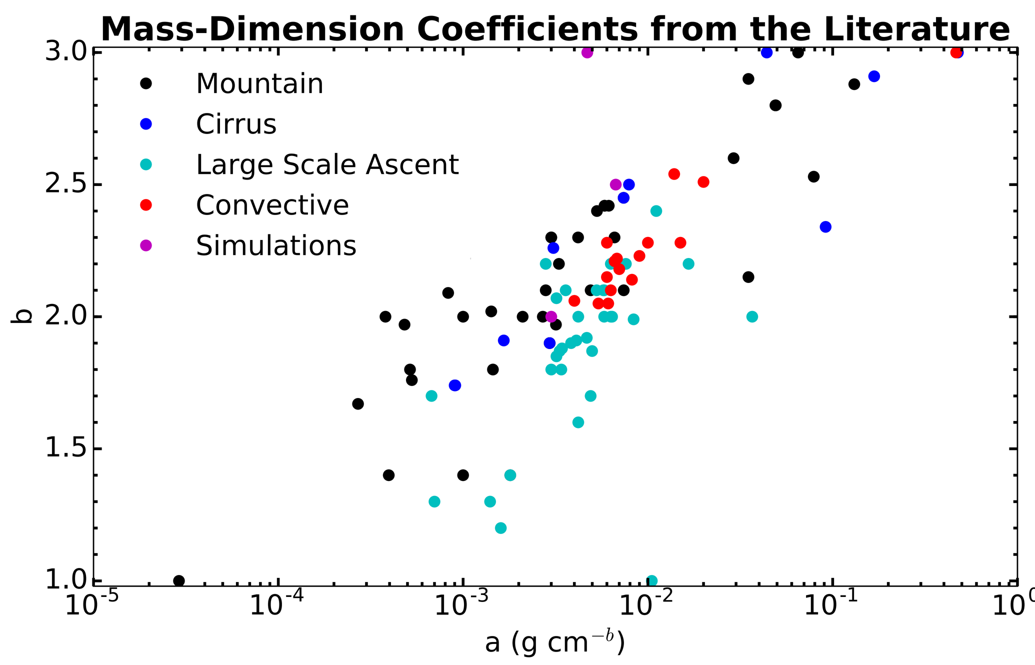
Key Points:

- Parametrization of PSDs using uncorrelated mass parameters gives IWC and Ze comparable to the PSD itself, Field et al. (2007) biased
- It is important to allow μ = 0 in ice at GPM-detectable PSDs
- A parameterization of the PSD using mass parameters (including *a*, *b* uncertainty) is being developed for GPM algorithms

2) Parameterization of mass in ice clouds: *Use observed radar reflectivity factor and PSDs to determine equally-realizable a and b coefficients in $m = aD^b$* (Finlon et al., in prep)

m – D parameter variability

Mass-dimension (*m – D*) relationships relate particle size to mass through $m = D^b$.
Parameters *a* and *b* vary with environmental conditions (below), particle shape, processing techniques, and even with probe used to obtain data. Rather than single value of *a* and *b*, a range of *a* and *b* may best represent *m – D* relationships for remote sensing studies.

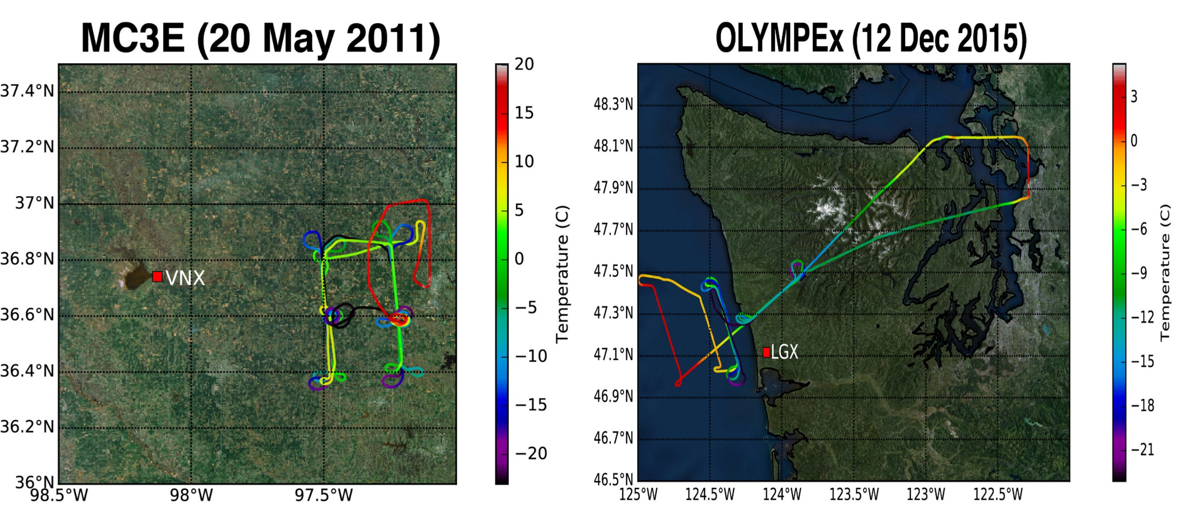


Distribution of *a-b* coefficients determined under different environmental conditions from many previous studies. Simulations denote scattering calculations performed.

Data from MC3E and OLYMPEX

For flight legs plotted below points where radar matching algorithm shows Univ. North Dakota Citation within 500 m of S-band radar gates identified, and radar reflectivity factor (Z_e) at aircraft's position determined by our radar matching code.

In MC3E PPI scans from KVNX WSR-88D were used in OLYMPEX, PPI scans from KLGX WSR-88D were used

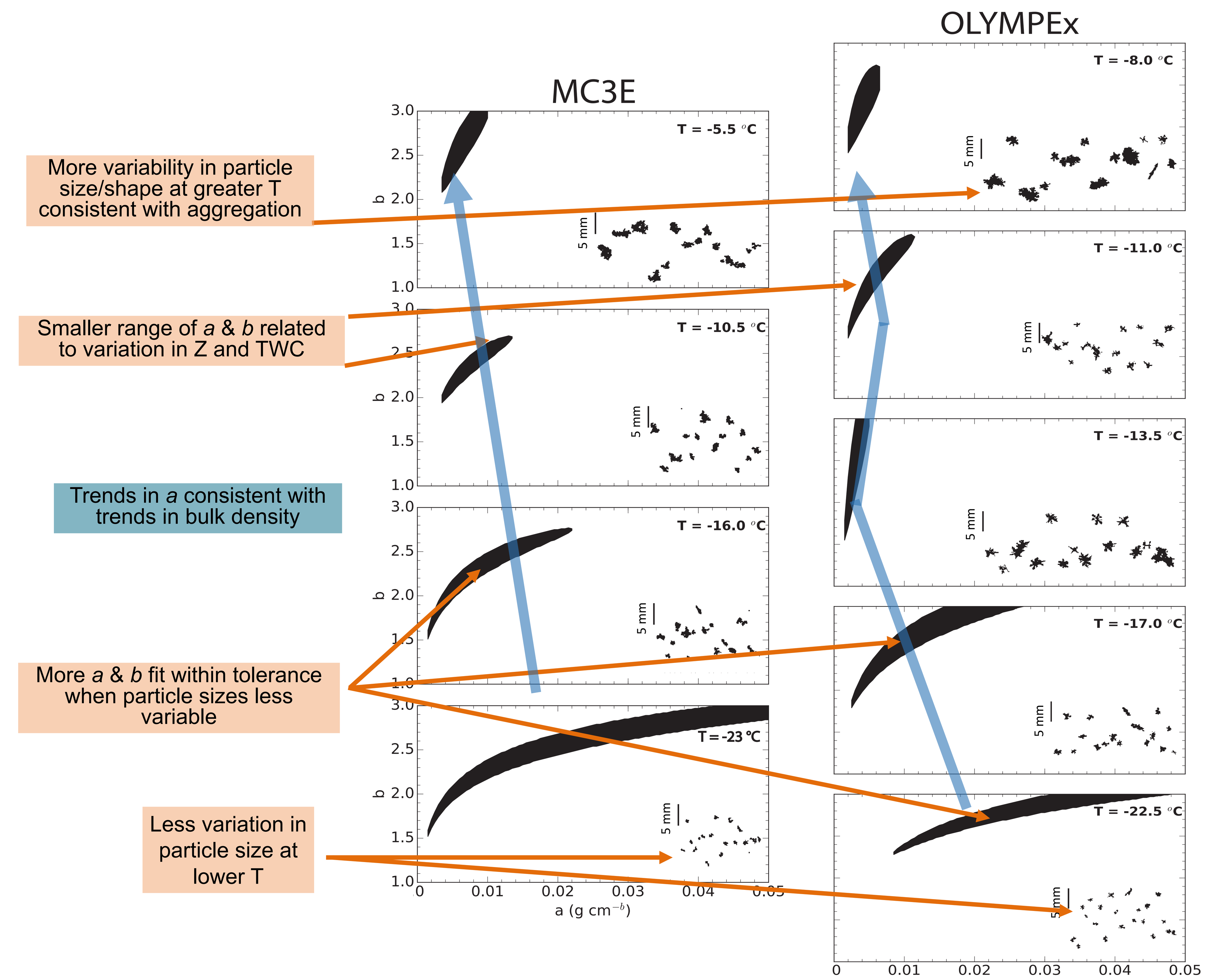


Map of Citation track (colored by temperature) and S-band radar location (red box) for 20 May 2011 of the Mid-Latitude Continental Convective Clouds Experiment (MC3E, left) and 12 Dec 2015 of the Olympic Mountain Experiment (OLYMPEX, right).

Uses technique similar to McFarquhar et al. (2015) where *a* and *b* minimizing X^2 difference – X^2min – between total water content (TWC) & Z are derived from particle size distributions (PSDs) and measured by Nevzorov TWC probe and S-band radar for each flight leg containing *N* collocated observations

Surface of equally realizable a & b coefficients in (a,b) phase space determined by accepting all coefficients satisfying $X^2(a,b) \le X^2$min + max(X^2 min, ΔX^2), where ΔX^2 is some tolerance based on statistical uncertainty in measured SDs

The figure at right shows surfaces of equally realizable *a* and *b* coefficients in (a, b) phase space for MC3E (left) and OLYMPEX (right) at different constant temperature environments. Representative particle images from the HVPS3 optical array probe (insets) also shown.



Key Points:

- Chi-square minimization technique employs novel way of determining range of a-b solutions describing meteorological conditions & microphysical properties in cloud
- Technique permits stochastic representation of *m – D* parameters within microphysical parameterizations & retrieval schemes
- Particle images corroborate trends in radar Z_e and TWC as a function of temperature, with aggregation more common at higher temperatures and within the dendritic growth zone
- Range of equally realizable *a* & *b* appear related to relative variability in observed Z and TWC for temperatures and cases analyzed
- Increasing *a* values toward lower T agree with bulk density trends in observed stratiform clouds

Acknowledgments

Funding from National Aeronautics and Space Administration, Precipitation Measurement Missions (grants: NNX16AB70G and NNX16AD80G)
Thanks to Wei Wu, Mike Poellot, Saisai Ding, and Bob Rauber for scientific discussions